Ecological impact assessments fail to reduce risk of bat casualties at wind farms

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Demand for renewable energy is rising exponentially. Whilst this has benefits in reducing greenhouse gas emissions, there may be costs to biodiversity [1]. Environmental Impact Assessments (EIAs) are the main tool used across the world to predict the overall positive and negative effects of renewable energy developments before planning consent is given, and the Ecological Impact Assessments (EcIAs) within them assess their species-specific effects. Given that EIAs are undertaken globally, are extremely expensive, and are enshrined in legislation, their place in evidence-based decision making deserves evaluation. Here we evaluate how well EIAs of wind-farm developments protect bats. We found they do not predict the risks posed to bats accurately, and even in those cases where high risk was correctly identified, the mitigation deployed was not effective in averting the risk. Given that the primary purpose of an EIA is to make planning decisions evidence-based, our results indicate that EIA mitigation strategies used to date have been ineffective in protecting bats. In future, greater emphasis should be placed on assessing the actual impacts post-construction and on developing effective mitigation strategies.

The high legal protection of bats (e.g. Europe: EUROBATS 2014 & Habitats Directive 1992; North America: Endangered Species Act 1973), together with the known risks to bats posed by wind farms (e.g. [2]), means that detailed preconstruction ecological assessments are frequently undertaken. Acoustic surveys are widely used to determine species presence/absence, and to provide an estimate of bat activity from which collision risk is inferred. However, bat activity is highly variable – both spatially and temporally. It is therefore unclear whether the survey protocols currently employed assess bat activity with sufficient precision and repeatability to be of practical value in inferring risk for developments which may not be constructed for many months or even years. Determining the best methods to assess likely impacts on bats from wind turbines is regarded as a research priority by EUROBATS guidelines [3]. To our knowledge, there has only been one study (in North America) that investigates the value of using bat activity to predict the risk to bats from future wind turbines. This found that pre-construction bat activity was not a significant indicator of collision risk [4], however the value of EIAs in predicting risk was not assessed. We therefore assessed the effectiveness of pre-construction EIAs as a tool to aid decision-makers in determining the impact of wind energy on bats.

We surveyed 46 wind farms across the UK for bat fatalities as part of a wider project investigating the impact of wind turbines on bats. We were able to obtain EcIAs for 29 of these sites, the remaining EcIAs were either not available as electronic copies or their location was unknown. Eighteen EcIAs concluded that a field assessment of bat presence/activity was not required at the proposed wind farm site (as evidenced by statements in the EcIA such as “Bat surveys are unnecessary as the development does not affect any features likely to be used by bats”), or inferred based on field surveys that there would be no significant effects on any protected species (*see also Table S1*). However, during our post-construction surveys we found that half of these sites contained casualties (ranging from one to 64 fatalities per month during the July-October survey period), and 97% had evidence of bat activity (ranging from one to 236 passes per night) during post-construction monitoring. The perception of risk to bats during EcIAs was not significant in predicting either bat casualty rates (Figure 1a) or activity levels post-construction (*see also Figure S1*). While there was a positive relationship between sites ranked by perceived risk to bat populations and sites ranked by casualties per month (Figure 1b), there was considerable scatter in the data and 9 sites identified as having the lowest risk had >1 casualty per month. Pre-construction sites perceived to be of high risk to bats (e.g. sites where extensive mitigation was undertaken, including moving turbines) had the highest casualty rates. By comparison, pre-construction sites perceived to pose little risk (e.g. sites where bats were only found at the periphery of the development) had relatively low levels of bat fatalities.

Our results show that sites which may have been perceived as of poor quality for bats can contain casualties after wind turbine construction. Similarly, bat activity recording during pre-construction surveys may not accurately reflect activity levels that may occur post-construction. This may be due to bats changing their behaviour following construction, as turbines can be bat attractors [5]. Bats may be attracted to wind farm sites for a variety of reasons including; i) the emission of ultrasound from turbines [6], increased prey availability, [5] and investigating turbines for potential roosting opportunities [7]. It is therefore essential that future mitigation strategies are formed with an understanding of how bat behaviour differs at sites after turbines have been constructed. Additionally, surveying effort has to be both spatially and temporally adequate to assess risks to bats in the first place.

Of those sites identified as posing a significant risk to bats in the EcIA surveys, risk does not appear to have been adequately mitigated. Indeed, one of these mitigated sites had the highest recorded casualty rate. In the UK, regulations state that ‘if significant harm cannot be avoided, adequately mitigated, or as a last resort, compensated for, planning permission should be refused' and similar legislation applies in many other countries. We conclude that significant harm was not avoided at these significant risk sites.

Given the economic cost of undertaking EcIAs, the value attached to their findings during planning applications and enquires, and the possible consequences to biodiversity of errors, it is vital that they are fit for purpose. We highlight that although EIAs give the perception of rigorous safeguarding of environmental standards and may portray energy companies with an environmentally friendly public image, considerable time and expense goes into deploying bat detectors at pre-construction sites with little justification. Although the use of EIAs have evolved and adapted differently between nations [8], there is a pressing global need to identify the procedures which can accurately identify risk to bats (e.g. Brazil [9]). We suggest that sites which are perceived to contain little collision threat to bats should be treated with caution until there is a greater understanding of how to identify risk factors to bats. On occasions when mitigation is currently deemed unnecessary, post-construction surveys should still be conducted (e.g. carcass searches) to ensure that the predictions are accurate and bat behaviour has not altered from pre-construction levels. Our results also highlight the importance of longitudinal monitoring of major developments and a feedback mechanism for practitioners to share the success or failure of mitigation strategies.

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Figure 1. The relationship between pre-construction assessment of risks to bats and post-construction fatalities: a) the difference in the average number of bat casualties per site between wind farms where preconstruction surveys perceived different levels of risk. Error bars depict the standard error around the mean. b) the marginally significant relationship between ranked pre-construction assessment of risk to bats and ranked post-construction fatality estimates (ρ (29) =0.36, p=0.05). Sites are ranked in ascending order of perceived risk. Circle size is proportional to the number of sites at a particular ranking (range 1 to 3 sites).

Supplemental Data Items

Table S1. Statement from Environmental Impact Assessments identifying the risk to bats posed by wind energy developments. Statements which identified potential risk to bats were ranked in order of severity. Statements have been paraphrased where appropriate to preserve the anonymity of the site

Example of statements inferring no risk to bats (n=20)	Rank
We conclude that there are no significant effects on protected species within the proposed development.	1
There will be a negligible effect on protected species and their habitats from this development.	1
There was no bat activity recorded within the site.	1
There is no risk to protected species.	1
Potential risk to bats	
Bats not active within study area, but surveys confirmed presence in adjacent areas to the study area	2
A low number of common pipistrelles on the edge of the site indicate that this area is of relatively poor value to bats.	3
Only bats recorded in activity surveys were found at the periphery of the site.	4
Nightly activity varied from 'single passes' to 'several', low impact overall	5
Common and soprano pipistrelles likely to use site, however no other species are likely to present	6
Suitability assessments around each turbine indicated that risk to foraging bats was negligible/low with the exception of 2 areas which were used frequently.	7
Moderate levels of pipistrelle bats were recorded alongside very low levels of *Myotis* and brown long-eared bats.	8
Results showed that 12 species used this site, however the impact was not considered significant	9
Development likely to impact bats, therefore mitigation to enhance surrounding landscape.	10
Site considered of local conservation value for foraging bats. Mitigation undertaken by placing turbines at least 50m from important foraging areas.	11
High impact on bats due to the loss of hedgerow foraging and commuting habitat. Mitigation undertaken by siting turbines to reduce impacts on bats.	12

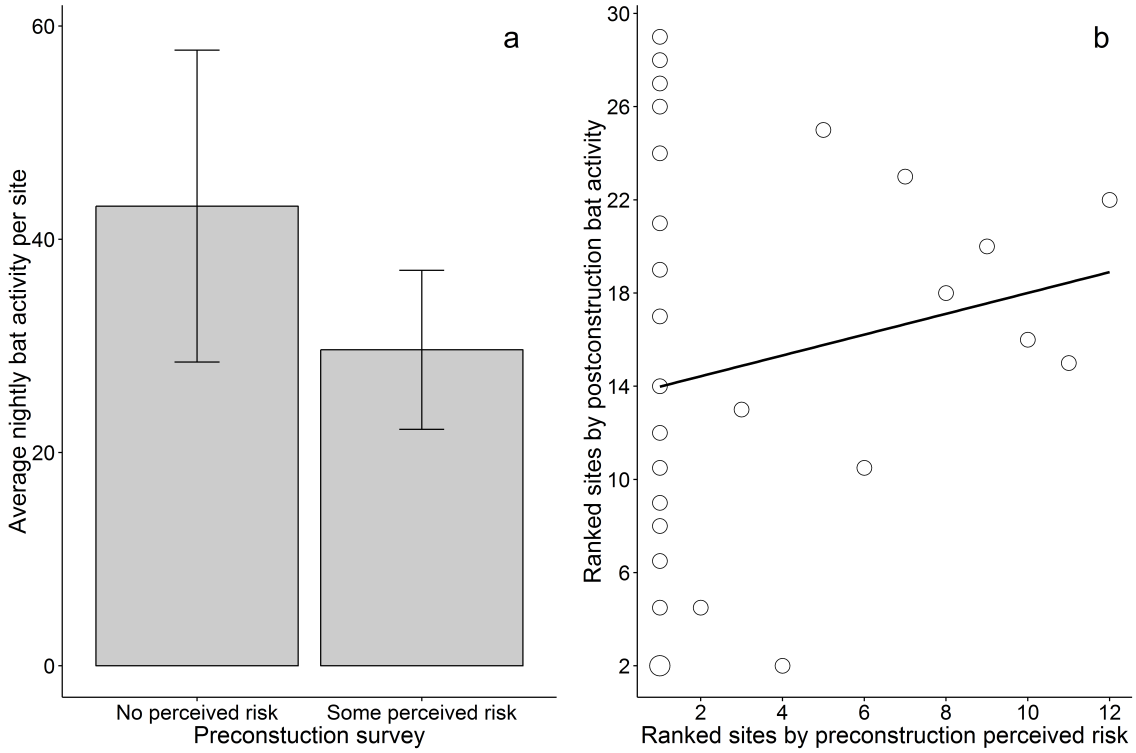

Figure S1. The relationship between pre-construction assessment of risks to bats and post-construction bat activity, a) the difference in the average nightly activity per site between wind farms where preconstruction surveys perceived different levels of risk. Error bars depict the standard error around the mean. b) the relationship between ranked pre-construction assessment of risk to bats and ranked post-construction bat activity (ρ (29) =0.11, p=0.57). Sites are ranked in ascending order of perceived risk. Circle size is proportional to the number of sites at a particular ranking (range 1 to 2 sites).

Supplemental Experimental Procedures

Methods

Site selection

We surveyed 46 wind farms across the UK for bat fatalities as part of a wider project investigating the impact of wind turbines on bats. We approached local planning authorities and ecological consultants to request copies of EIAs/EcIAs for relevant wind farms. Of the 46 wind farms that were surveyed for bat fatalities, we were able to obtain relevant information from 29. The remaining EIAs/EcIAs were either not available as electronic copies or the location of hard copies were unknown and could not be identified by current owners/operators or local authorities.

Assessing Environmental Impact Assessments

We searched each EIA/EcIA for any reference to bats and where mentioned the following details were noted: i) surveying methodology, ii) assessment of bat presence and activity within site, iii) risk posed to bat populations, and iv) mitigation strategies undertaken. We classified each site by its perceived risk to bats within two categories; i) no risk to bats, ii) potential risk to bats (Table S1). Sites were ranked based on their perceived risk to bats (the order of the rankings was verified by asking ten bat scientists to independently rank the sites and averaging their results). This ranged from sites where desk-based surveys concluded there was no risk to bats, to sites where bats were only found at the periphery of the development to sites where extensive mitigation strategies were undertaken including situating turbines a substantial distance away from a network of treelines and hedgerows (Table S1). Where mitigation was undertaken we visually assessed these sites using satellite imagery (e.g. distance of turbines from linear features) to ensure that mitigation strategies had been carried out.

Quantifying bat fatalities at wind farms

We searched six randomly selected turbines at each site for approximately one month between July and October (mean duration 27 day, SD 6). A 100 x 100m square centred on each turbine was searched by a trained dog-handler team following Mathews et al. 2013). The habitat underneath each wind turbine was recorded on a standard pro-forma. Surveying was conducted early in the morning to minimise the removal of carcasses by diurnal scavengers (e.g. corvids). The mean search interval was three days (SD 0.03), and each turbine was searched a mean of 11 times. If a carcass was identified, its location and condition were noted and an estimate of the date of death was made. Wing and fur samples were also taken to allow for genetic examination and analysis of stable isotope composition which could provide evidence of whether any migratory bats were killed. Carcasses were identified to species using PCR or by morphometric measurements if genetic identification failed (Hamilton et al. 2015).

The number of individuals found during carcass searches will be an underestimate of the true casualty rate. This is primarily due to two main factors: i) searcher efficiency (the probability that an observer will find a carcass if it is present), and ii) carcass removal (by scavengers, decay or the weather). We therefore conducted efficiency trials at each site to estimate the efficiency of the dog-handler team at finding bat carcasses. An independent observer placed bat carcasses (between 3 and 14 bats (mean of six bats per trial); predominantly *Pipistrellus* spp.) randomly around a 100m x 100m area of similar habitat within the wind farm which was not being searched as part of the study. We then assessed how many carcasses the dog-handler team found with no *a-priori* knowledge of the number or location of the bats. Observations only stopped if all carcasses were removed, or when surveying finished at a particular site. Additionally, we conducted carcass removal trials to estimate the rate removals by predation and/or decay through the duration of the study at each site. These two measures allowed us to account for differing levels of carcass removal and observer efficiency between sites (e.g. differences in vegetation cover) and across time (e.g. differences in weather conditions). For each site, we then estimated the proportion of bats removed during the mean number of days between searches (inter-search interval). An estimate of the true casualty rate per standard month (30 days) per turbine was computed as follows:

$$Estimate = \frac{n \times Days}{ET \times CRT \times T}$$

n = number of bats found
T = number of turbines searched
ET = proportion of bats found in efficiency trials
CRT = estimate of carcass removal rate
Days = number of days in the month

Quantifying bat activity at wind farms

We placed three full spectrum acoustic bat recorders (SongMeter2 (SM2 and SM2+), Wildlife Acoustics USA)) on either 2m high tripods or on the steps leading up to the turbine at each of the 46 wind farm sites. We programmed each detector to make automatic nightly recordings starting 30 minutes before sunset and ending 30 minutes after sunrise. We recorded bat activity at each site for an average of 27(± SD 8) continuous nights.

Sound Analysis

We processed bat calls with Kaleidoscope Pro (v.1.1.20, Wildlife Acoustics, Massachusetts, USA) with British bat classifiers (v.1.0.5). Noise files were removed and all bat sonograms were manually verified to species level (with the exception of *Myotis* spp. and *Plecotus* spp. which were identified to genus level and were grouped together within genera-wide categories). A bat pass was defined as a continuous sequence of passes separated by a minimum of one second from other passes.

Data analysis

Data analysis was undertaken using R version 2.14 (R Core Team, 2012) and plots were produced using the ggplot2 package (Wickham, 2009).

We performed Mann-Whitney U tests to determine if there was a difference in either post-construction bat activity or fatalities based on whether pre-construction surveys identified the presence or absence of bats.

Spearman's Rank correlation coefficient was used to assess the relationship between the rank of perceived risk to bats (based on EcIA – see section 3.2) and the rank of the casualty rate. The same approach was used to assess the link with the rank of bat activity.

Results

Eighteen EIAs concluded that an assessment of bat presence/activity was not required at the proposed wind farm site, or that there would be no significant effects on any protected species. However, half of these sites subsequently were found to have bat casualties (ranging from one to 64 per month) and 89% of these sites had evidence of bat activity post-construction (ranging from one to 236 passes per night).

The binary classification of sites according to whether bats were present or absent at the pre-construction survey was not linked with casualty risk (Mann-Whitney *U* test: U = 66.5, N_1 = 11, N_2 = 18, P = 0.14; Figure 1). Similarly, the reported presence or absence of bats pre-construction was not related to post-construction bat activity (Mann-Whitney *U* test: U = 95, N_1 = 11, N_2 = 18, P = 0.87; Figure S1a).

There was a significant, but marginal, positive relationship (ρ (29) =0.36, p=0.05) between the rank of perceived risk to bat populations casualty risk(Figure 3). Sites perceived to be of high risk to bats pre-construction had the highest casualty rates, whereas those with little bat activity (Table S1) had relatively low levels of bat fatalities. There was no significant relationship (ρ (29) =0.11, p=0.57) between sites ranked be perceived risk to bat populations and sites ranked by bat activity (Figure S1b).

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